AD-A036 609 NAVAL UNDERSEA WARFARE CENTER SAN DIEGO CALIF F/G 20/1
CALCULATION OF ABSORPTION COEFFICIENT USING AVERAGE TEMPERATURE--ETC(U)
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UNCLASSIFIED NUWC-TN-126 NL

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(16) F10103, ZR01101

MOST Project -2

(17) SF10103211, ZR0110101

(14) NUWC-TN-126

(1)

NAVAL UNDERSEA WARFARE CENTER

(11) JUNE 1968

(12) 25p.

(9) Technical note,

(6)

CALCULATION OF ABSORPTION COEFFICIENT USING AVERAGE TEMPERATURE AND PRESSURE.

TN 126

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San Diego, California

SUBPROJECT NO. ZR0110101

TASK NO. 0401

403023

This technical note describes a calculation procedure for a prediction model presently in use at the Naval Undersea Warfare Center, San Diego Division. This note is not to be considered as an official NUWC report. Its purpose is to document the existing model to the extent required by Navy project offices for whom predictions have been made.

The work described in this report has been supported under NAVSHIPS Exploratory Development subproject SF 101 03 21, Task 8704, and by Independent Research funds under NAVSHIPS subproject ZR 011 01 01.

INTRODUCTION

This note describes the investigation of an expression to be used in bottom bounce propagation models presently in use at NUWC Code D556. Recently an expression[1] was developed to predict the acoustic absorption coefficient of seawater from the frequency, temperature, pressure and salinity. This expression was developed from a combination of existing equations in order to provide a single prediction expression valid under all operating conditions.[2,3]

In the past many methods of calculating the absorption coefficient have been used. These methods include the use of the surface temperature and 50°F in empirical expressions.[3] This paper shows that it is necessary for the sake of accuracy to use the temperature averaged over the path of the propagating ray and to include the pressure term.

SUMMARY AND CONCLUSIONS:

The acoustic absorption coefficient (α) of sea water for any particular point is a function of the temperature (T) and the pressure (P) at that point, as well as the frequency (f) and the relaxation frequency (f_T). Several methods of averaging α over temperature-depth profiles were compared for accuracy and ease of computation. The difference between the absorption calculated using depth-averaged temperature and that using the surface temperature or the bottom temperature is shown in figure 3. The temperature can be averaged in Procedure RAYTRACE* by using the existing values of depth and time increment with five new ETRAN statements.

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*Procedure RAYTRACE is a computer program which computes raypath parameters using Snell's Law and a velocity profile comprised of constant gradient sections.

The absorption loss results compare favorably with those calculated using each temperature and averaging the results.

Errors due to deletion of the pressure term in α calculations can be significant at large depths ($>2x10^4$ ft) and higher frequencies (>3kHz). Neglecting the increase in density, the static pressure is a linear function of depth and can be averaged in Procedure RAYTRACE with the addition of three new statements.

PROCEDURE:

The expression for the acoustic absorption of sea water[1] is

$$\alpha = \frac{1.776f^{1.5}}{32.768+f^3} + \left(\frac{1-6.54x10^{-4}P}{1+32.768/f^3}\right) \cdot \left(\frac{.6505f_T f^2}{f^2+f_T{}^2} + \frac{.02685f^2}{f_T}\right) \quad \text{dB/kyd}$$

where f_T is calculated as below.

$$f_T = 21.9x10^{(6T+118)/(T+213)} \text{ kHz}$$

The average temperature is calculated from

$$T = \frac{1}{t} \sum_{k=1}^{n} T_k t_k$$

where T_k is the temperature during the time period t_k and t is the total time during the averaging process. The average relaxation frequency was calculated in the same manner.

The coefficient of absorption was calculated separately using the average temperature, the average relaxation frequency, the surface temperature, and the bottom temperature. The coefficient was also determined for each break in the temperature-depth profile and averaged to provide a physically accurate value for comparison.

The above calculations were made for several temperature-depth profiles derived from bathythermograph and Nansen cast data (figure 1) assuming that the time spent at each temperature is proportional to the depth interval of that temperature. Calculations were then made for a general profile (figure 2) using time intervals calculated by Procedure RAYTRACE, which gives the actual time spent by the ray in each depth interval.

The values of α as a function of frequency resulting from the application of these averaging techniques to the general profile are shown in figure 3. It is seen that the value determined through temperature averaging is nearly equal to the corresponding value determined by averaging the coefficients for each temperature along the profile.

The differences between the absorption loss at a range of 50 kyd determined by the surface and the bottom temperatures are shown in figure 4. Results are shown for several operating frequencies. Figures 5, 6 and 7 show a comparison of α determined using the surface temperature, the bottom temperature, and the average temperature for several varied temperature profiles at a reference distance of one kiloyard.

The variations in the absorption loss caused by pressure are shown in figure 8 for several frequencies and depths.

The temperature and pressure averaging procedures described in this note are being implemented in a modified Procedure RAYTRACE[4] which will be documented in the near future. A direct application of this technique is in the Bottom Bounce Propagation Mode. Adaptations are also being considered for the Convergence Zone Mode.

A table is inserted at the end of the report listing the absorption as a function of frequency and temperature for several pressures. Zero pressure is also listed and will coincide with values previously presented.[5] The depth in feet required to produce the pressure is also listed.

REFERENCES:

1. Hall, H. R. and Watson, W. H., "A New Absorption Coefficient Expression for Use in Sonar Range Prediction", U. S. Navy Journal of Underwater Acoustics, CONFIDENTIAL, October 1967.

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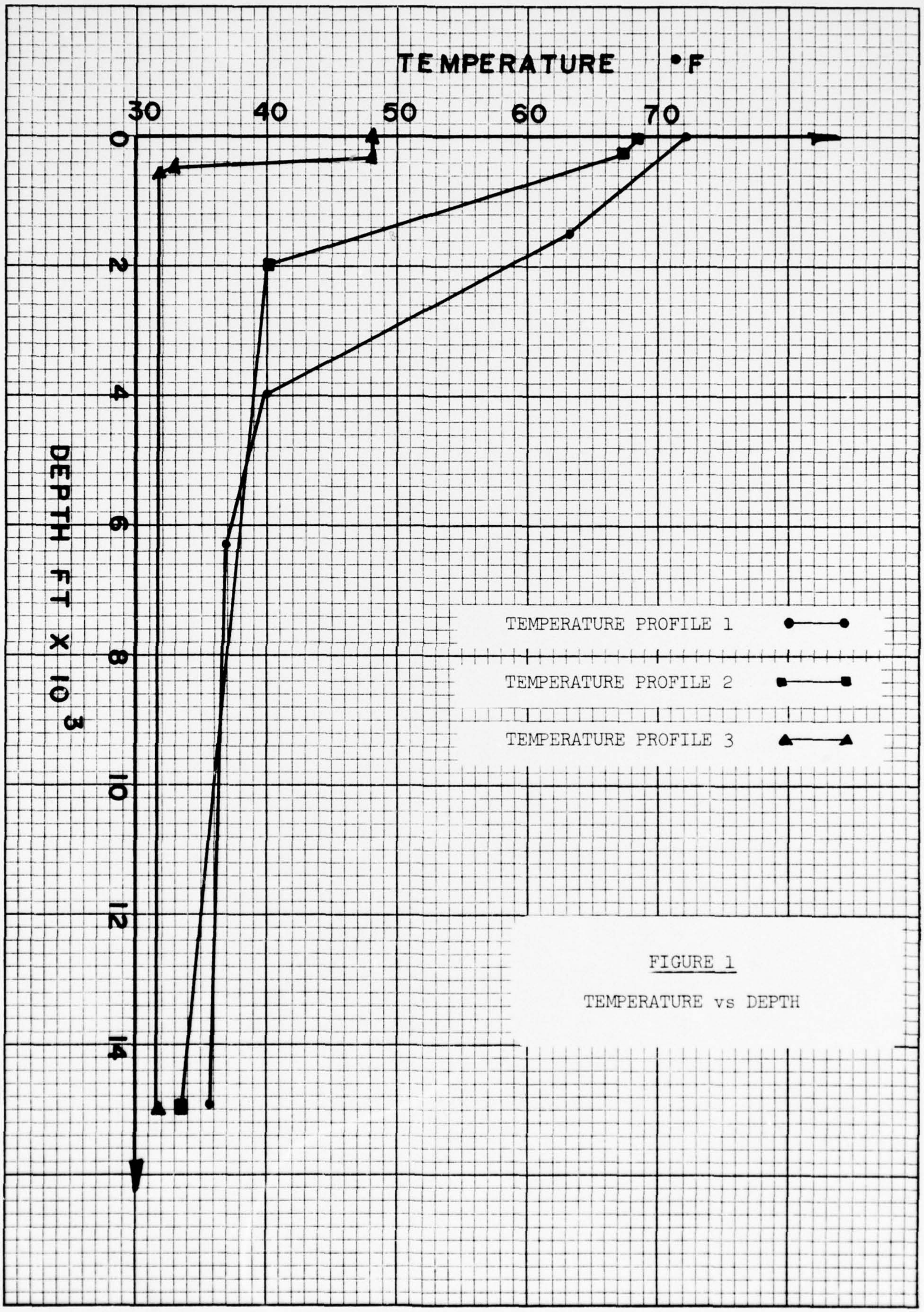
4. Naval Undersea Warfare Center, Code D556 Internal Report 4, Interim Report on Procedure RAYTRACE, by Dr. H. R. Hall, May 1967.

5. Naval Undersea Warfare Center Technical Note 63, Values of the New Acoustic Absorption Coefficient of Seawater, Dr. H. R. Hall, February 1968.


TEMPERATURE °F
30
40
50
60
70
DEPTH FT X 10 3
0
2
4
6
8
10
12
14
TEMPERATURE PROFILE 1
TEMPERATURE PROFILE 2
TEMPERATURE PROFILE 3
FIGURE 1
TEMPERATURE vs DEPTH

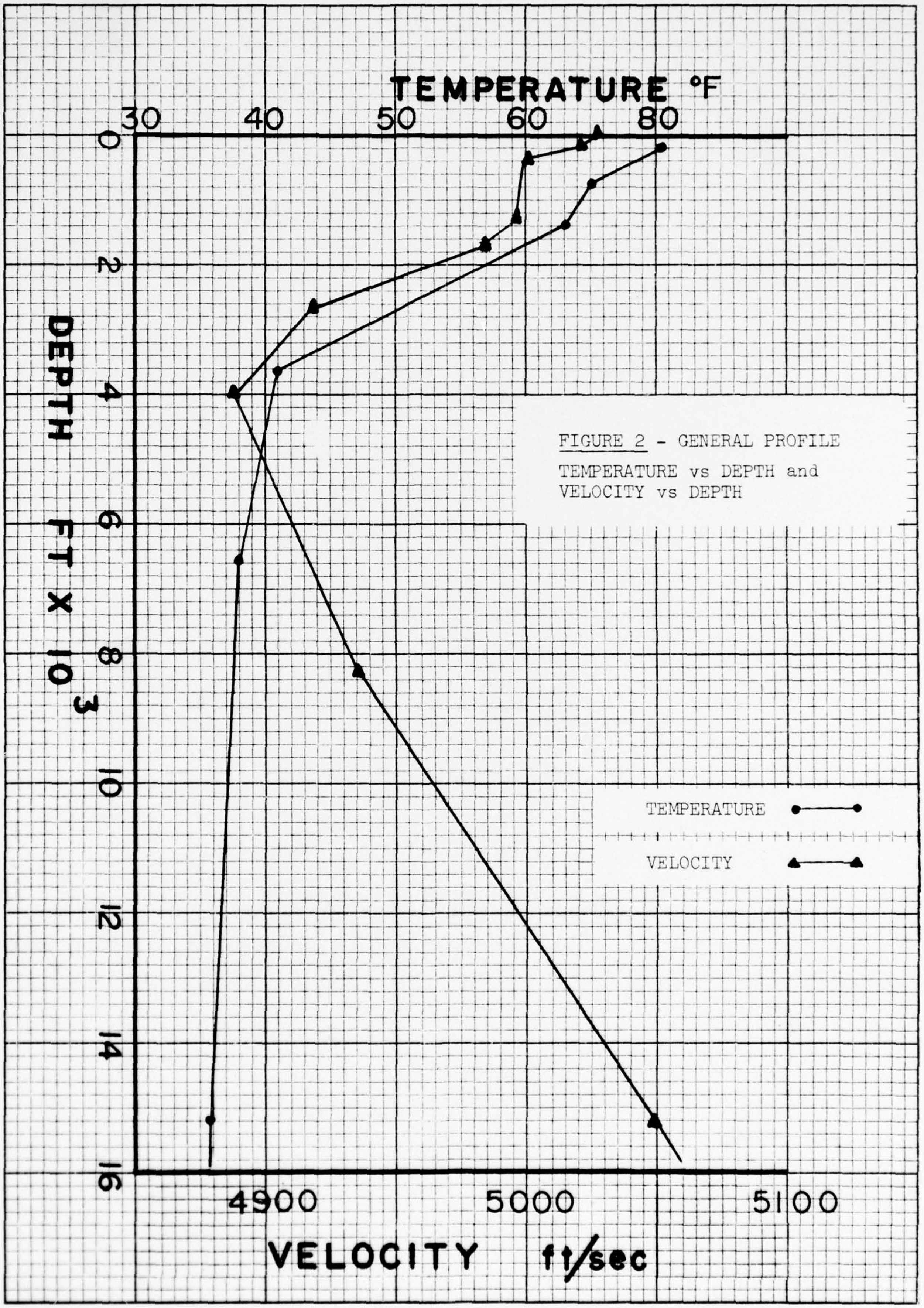


FIGURE 2 - GENERAL PROFILE

TEMPERATURE vs DEPTH and
VELOCITY vs DEPTH

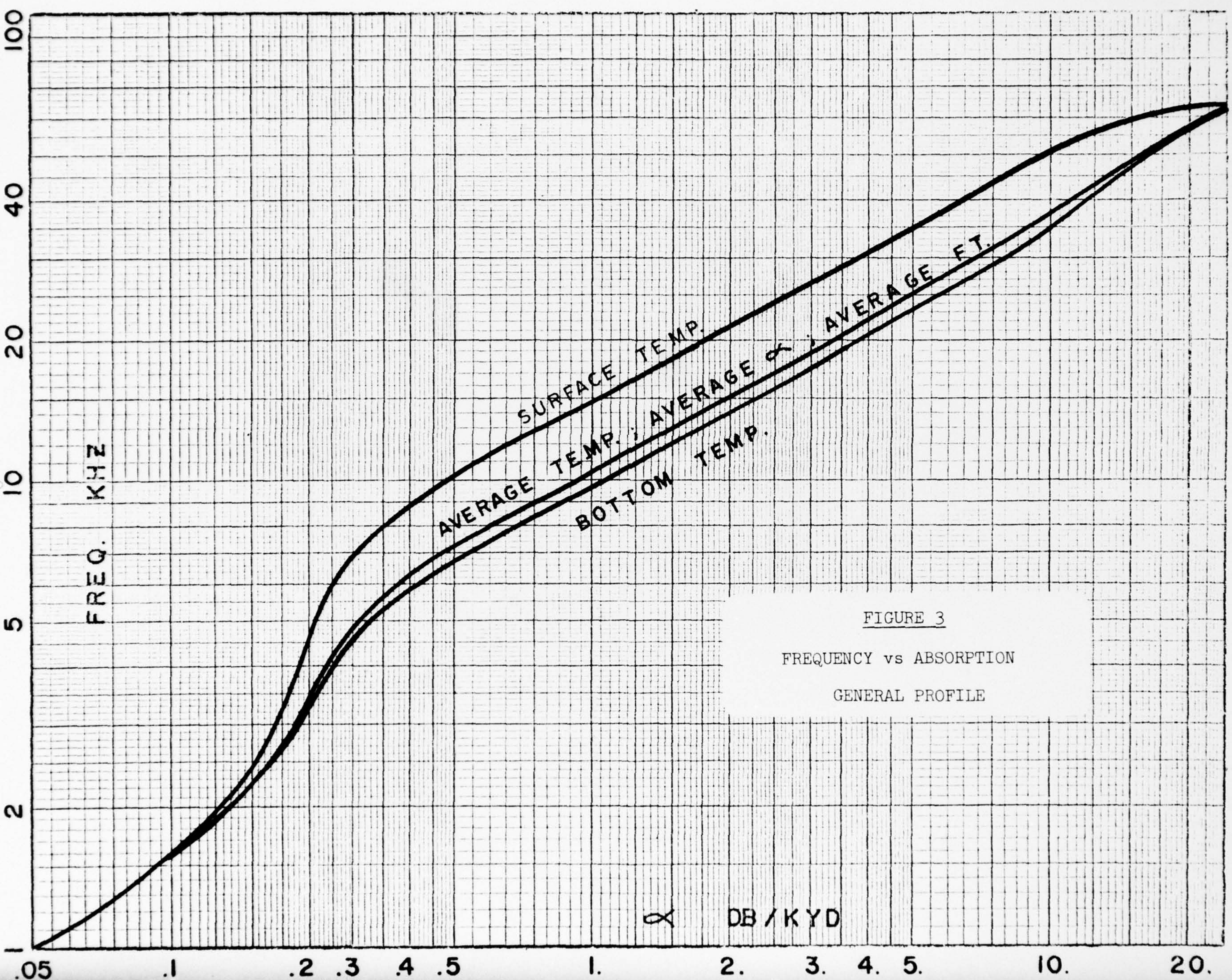


FIGURE 3

FREQUENCY vs ABSORPTION

GENERAL PROFILE

Comparison of the Absorption Loss calculated from the average temperature ($\bar{T}$) with that calculated from the bottom temperature (T_B) and the surface temperature (T_S).

Frequency khz	$\left(\alpha(\bar{T})-\alpha(T_S)\right)\times 50$ dB at 50 kyd	$\left(\alpha(\bar{T})-\alpha(T_B)\right)\times 50$ dB at 50 kyd
1	.007 dB	-.002 dB
2	.176	-.051
3	.91	-.26
4	2.37	-.68
5	4.42	-1.27
6	6.95	-1.99
7	9.91	-2.83
8	13.27	-3.78
9	17.03	-4.83
10	21.16	-6.0
20	80.24	-20.8
30	158.8	-36.0
40	236.7	-44.5
50	299.5	-43.3
75	326.4	-7.93

Figure Four

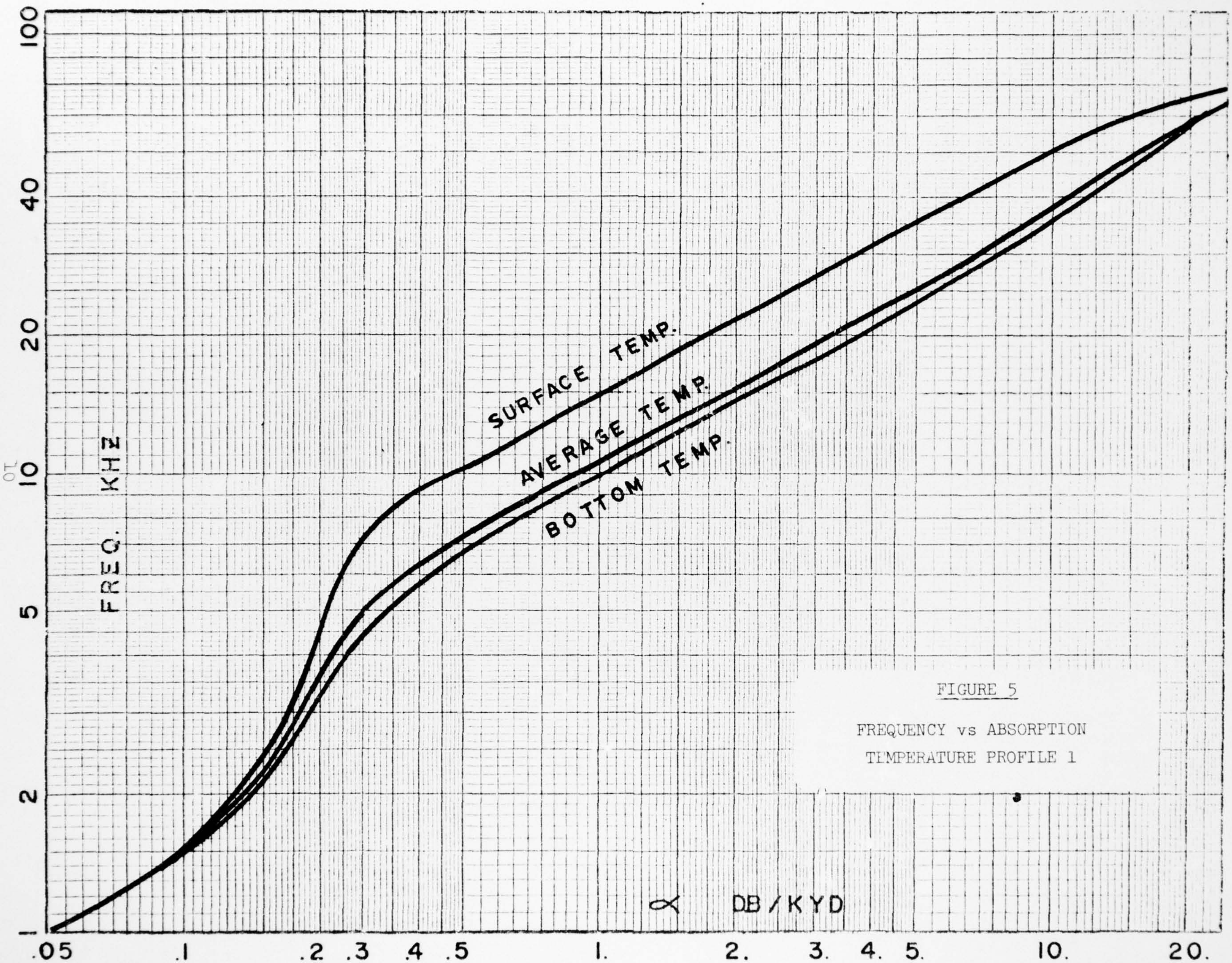


FIGURE 5

FREQUENCY vs ABSORPTION

TEMPERATURE PROFILE 1

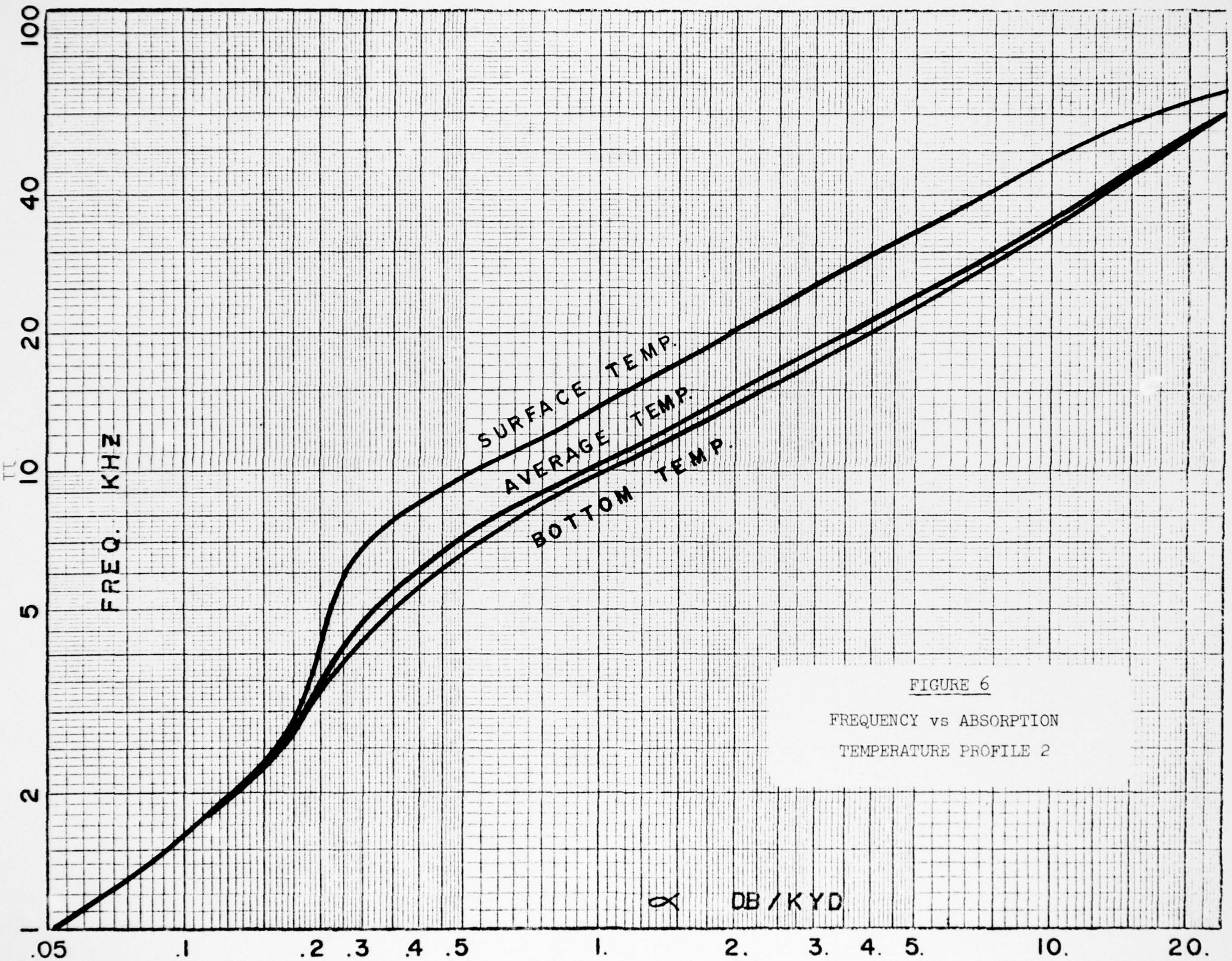


FIGURE 6

FREQUENCY vs ABSORPTION

TEMPERATURE PROFILE 2

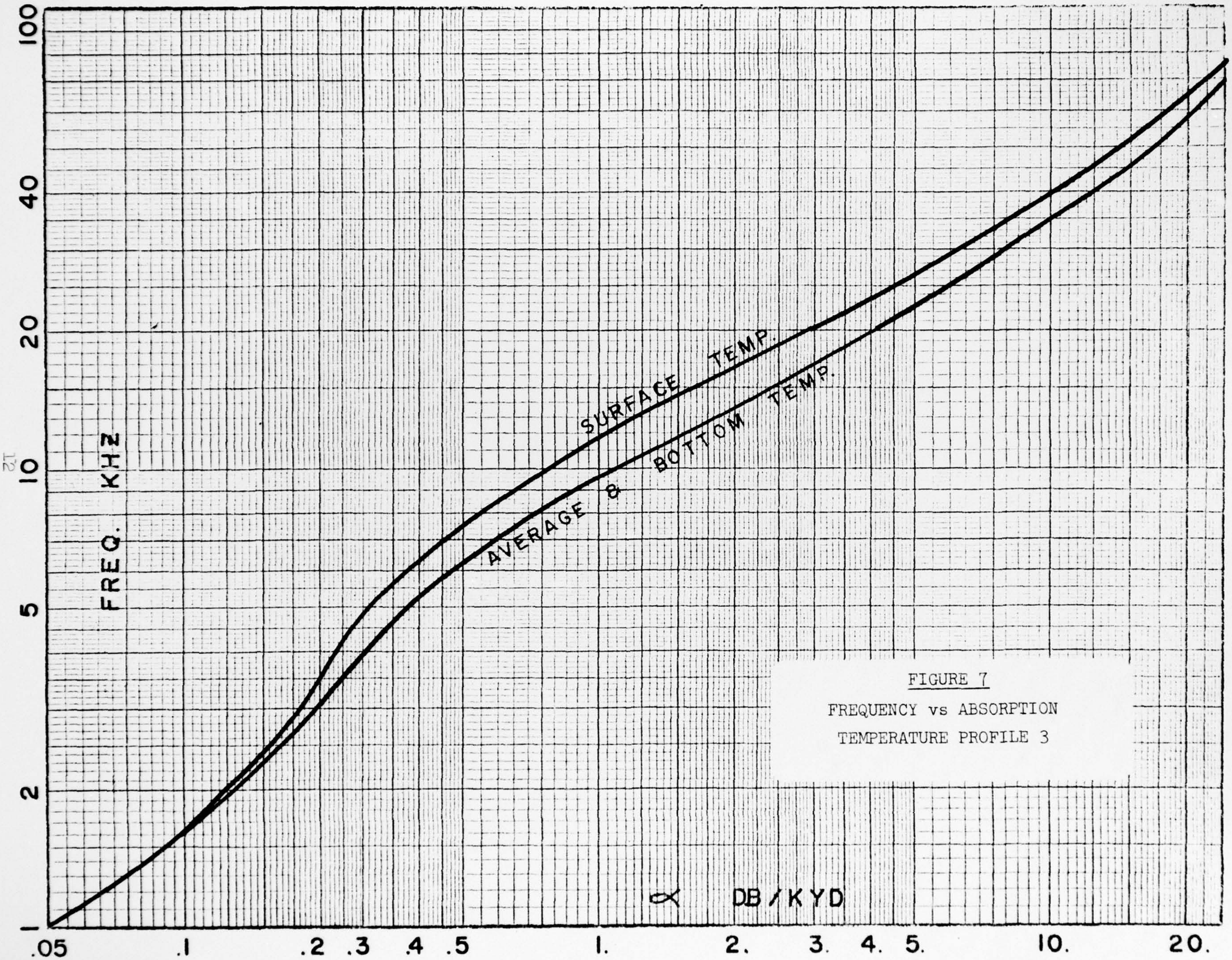


FIGURE 7

FREQUENCY vs ABSORPTION

TEMPERATURE PROFILE 3

FREQUENCY (kHz)	AVERAGE DEPTH (kft)	α $(\bar{P})$ (dB/kyd)	α (dB/kyd)	dB DIFFERENCE AT 50 kyd
1	5	0.0527	0.053	0.015
1	10	0.0524	0.053	0.03
1	15	0.0521	0.053	0.045
2	5	0.129	0.13	0.05
2	10	0.128	0.13	0.10
2	15	0.127	0.13	0.15
3	5	0.186	0.19	0.20
3	10	0.182	0.19	0.40
3	15	0.178	0.19	0.61
4	5	0.231	0.24	0.45
4	10	0.222	0.24	0.91
4	15	0.213	0.24	1.36
5	5	0.283	0.30	0.86
5	10	0.267	0.30	1.67
5	15	0.249	0.30	2.58
10	5	0.83	0.91	4.04
10	10	0.751	0.91	8.03
10	15	0.67	0.91	12.12
20	5	3.03	3.36	16.7
20	10	2.71	3.36	32.8
20	15	2.47	3.36	45.

Figure 8. Comparison of α calculated with and without pressure term.

TABLES - ABSORPTION COEFFICIENT vs FREQUENCY (kHz) AND TEMPERATURE (°F) FOR VARIOUS PRESSURES (DECIBARS)

PRESSURE .00 DEPTH EQUIVALENT 0.

	TEMPERATURE			
FREQ	25	30	35	40
2.0	.134001	.132663	.131512	.130520
2.2	.153672	.151448	.149536	.147886
2.5	.172768	.169336	.166383	.163836
2.8	.195212	.189871	.185275	.181309
3.1	.217685	.209928	.203250	.197486
3.5	.248318	.237081	.226970	.218240
4.0	.291519	.273701	.258338	.245064
4.5	.340156	.315188	.293638	.275003
5.0	.395740	.362700	.334150	.309441
5.6	.472144	.426350	.390451	.357612
6.3	.574689	.517044	.467057	.423678
7.0	.691267	.618501	.555260	.500288
8.0	.860990	.784642	.700608	.627361
9.0	1.096439	.974442	.867604	.774197
10.0	1.336021	1.136588	1.055140	.939820
12.5	2.031055	1.807196	1.607664	1.430855
16.0	3.201485	2.867161	2.562248	2.287292
20.0	4.755524	4.301529	3.873833	3.478455

	TEMPERATURE			
FREQ	45	50	55	60
2.0	.129663	.128920	.128275	.127713
2.2	.146461	.145225	.144152	.143217
2.5	.161634	.159726	.158068	.156624
2.8	.177880	.174908	.172325	.170075
3.1	.192501	.188179	.184422	.181150
3.5	.210686	.204135	.198440	.193477
4.0	.233573	.223603	.214932	.207376
4.5	.258862	.244853	.232664	.222039
5.0	.288024	.269426	.253239	.239125
5.6	.329124	.304369	.282811	.264007
6.3	.386004	.353237	.324683	.299764
7.0	.452484	.410865	.374571	.342878
8.0	.563534	.507880	.459285	.416811
9.0	.692612	.621345	.559033	.504515
10.0	.838831	.750443	.673041	.605239
12.5	1.274339	1.137478	1.016649	.910438
16.0	2.041389	1.822657	1.628714	1.457180
20.0	3.113065	2.792759	2.501041	2.240746

PRESSURE .00 DEPTH EQUIVALENT 0.

FREQ	TEMPERATURE 65	70	75	80
2.0	.127222	.126793	.126416	.126085
2.2	.142401	.141687	.141060	.140510
2.5	.155363	.154259	.153291	.152441
2.8	.168110	.166390	.164882	.163557
3.1	.178292	.175791	.173597	.171668
3.5	.189143	.185350	.182022	.179096
4.0	.200775	.194997	.189927	.185470
4.5	.212756	.204629	.197496	.191225
5.0	.226790	.215989	.206509	.198173
5.6	.247567	.233170	.220530	.209415
6.3	.277970	.258875	.242110	.227362
7.0	.315147	.290843	.269496	.250716
8.0	.379521	.347008	.318350	.293129
9.0	.456736	.414813	.377955	.345505
10.0	.545765	.493544	.447605	.407143
12.5	.817019	.734818	.662387	.598507
16.0	1.305586	1.171696	1.053377	.948789
20.0	2.009132	1.803473	1.620962	1.459095

FREQ	TEMPERATURE 85	90	95	100
2.0	.125793	.125536	.125308	.125106
2.2	.140024	.139596	.139217	.138881
2.5	.151691	.151029	.150444	.149925
2.8	.162386	.161357	.160445	.159636
3.1	.169966	.168468	.167141	.165964
3.5	.176518	.174242	.172229	.170444
4.0	.181542	.178074	.175007	.172286
4.5	.185699	.180819	.176502	.172673
5.0	.190826	.184338	.178598	.173507
5.6	.199616	.190963	.183307	.176516
6.3	.214360	.202877	.192715	.183702
7.0	.234155	.219527	.206581	.195096
8.0	.270883	.251228	.233831	.218396
9.0	.316873	.291570	.269169	.249292
10.0	.371428	.339859	.311903	.287094
12.5	.542067	.492136	.447892	.408605
16.0	.856209	.774189	.701431	.636763
20.0	1.315443	1.187912	1.074594	.973743

PRESSURE 45.45 DEPTH EQUIVALENT 1500.

	TEMPERATURE			
FREQ	25	30	35	40
2.0	.133661	.132382	.131266	.130303
2.2	.153139	.150981	.149126	.147525
2.5	.171943	.168614	.165750	.163278
2.8	.193936	.188747	.184288	.180440
3.1	.215823	.208294	.201814	.196222
3.5	.245992	.234604	.224793	.216322
4.0	.287218	.269930	.255024	.242144
4.5	.334112	.309886	.288977	.270896
5.0	.387717	.355659	.327959	.303984
5.6	.461460	.418974	.382202	.350339
6.3	.560556	.504626	.456125	.414036
7.0	.673320	.602717	.541356	.488019
8.0	.856995	.753511	.681975	.610905
9.0	1.065718	.947347	.843686	.753054
10.0	1.297922	1.152931	1.025391	.913500
12.5	1.971357	1.754650	1.561050	1.389496
16.0	3.107136	2.782749	2.486900	2.220119
20.0	4.614746	4.174255	3.759270	3.375645

	TEMPERATURE			
FREQ	45	50	55	60
2.0	.129471	.128751	.128124	.127579
2.2	.146142	.144943	.143902	.142995
2.5	.161142	.159291	.157682	.156280
2.8	.177113	.174229	.171723	.169539
3.1	.191385	.187192	.133546	.180371
3.5	.208993	.202637	.197111	.192296
4.0	.230394	.221321	.212908	.205576
4.5	.255236	.241643	.229815	.219507
5.0	.283204	.265159	.249453	.235758
5.6	.322598	.298679	.277761	.259516
6.3	.377481	.345689	.317983	.293805
7.0	.441635	.401254	.366038	.335288
8.0	.543975	.494976	.447325	.406614
9.0	.673394	.604746	.544287	.491389
10.0	.815513	.729753	.654652	.588864
12.5	1.233119	1.104859	.987604	.884550
16.0	1.981527	1.769295	1.581118	1.414684
20.0	3.025967	2.710327	2.427284	2.174725

PRESSURE 45.45 DEPTH EQUIVALENT 1500.

FREQ	65	70	75	80
		TEMPERATURE		
2.0	.127103	.126686	.126321	.126000
2.2	.142203	.141510	.140902	.140368
2.5	.155057	.153986	.153047	.152221
2.8	.167633	.165965	.164501	.163215
3.1	.177598	.175171	.173042	.171171
3.5	.188091	.184410	.181181	.178343
4.0	.199172	.193565	.188646	.184322
4.5	.210499	.202614	.195693	.189609
5.0	.223790	.213310	.204112	.196024
5.6	.243566	.229596	.217332	.206547
6.3	.272659	.254132	.237864	.223556
7.0	.303381	.284800	.264088	.245865
8.0	.370529	.338886	.311080	.286609
9.0	.445031	.404353	.368591	.337106
10.0	.531158	.480489	.435916	.396656
12.5	.793907	.714149	.643872	.581890
16.0	1.267595	1.137686	1.022884	.921403
20.0	1.949999	1.750450	1.573366	1.416311

FREQ	85	90	95	100
		TEMPERATURE		
2.0	.125717	.125467	.125246	.125050
2.2	.139897	.139482	.139114	.138788
2.5	.151494	.150852	.150284	.149781
2.8	.162081	.161081	.160196	.159411
3.1	.169522	.168066	.166779	.165637
3.5	.175341	.173633	.171679	.169947
4.0	.180510	.177146	.174169	.171529
4.5	.184246	.179512	.175323	.171608
5.0	.188895	.182600	.177031	.172091
5.6	.197040	.188644	.181215	.174626
6.3	.210940	.199798	.189938	.181193
7.0	.229797	.215603	.203042	.191899
8.0	.265023	.245953	.229074	.214097
9.0	.309325	.284774	.263040	.243753
10.0	.362004	.331373	.304249	.280176
12.5	.527128	.478681	.435753	.397634
16.0	.831576	.751995	.681399	.619652
20.0	1.276926	1.153187	1.043238	.945386

PRESSURE 151.50 DEPTH EQUIVALENT 5000.

FREQ	TEMPERATURE 25	30	35	40
2.0	.132933	.131727	.130691	.129797
2.2	.151896	.149692	.148169	.146683
2.5	.170024	.166931	.164271	.161977
2.8	.190937	.186126	.181985	.178412
3.1	.211469	.204481	.198464	.193272
3.5	.239398	.228823	.219714	.211849
4.0	.277183	.261130	.247290	.235330
4.5	.320011	.297517	.278102	.261314
5.0	.368999	.339233	.313512	.291251
5.6	.436553	.397099	.362955	.333370
6.3	.527586	.475653	.430619	.391538
7.0	.631448	.565892	.508917	.459392
8.0	.801010	.714208	.638500	.572510
9.0	.994040	.884129	.787878	.703724
10.0	1.209032	1.074406	.955983	.852089
12.5	1.833733	1.632051	1.452291	1.292999
16.0	2.867005	2.585804	2.311104	2.063389
20.0	4.286301	3.877293	3.491966	3.135761

FREQ	TEMPERATURE 45	50	55	60
2.0	.129025	.128355	.127774	.127267
2.2	.145398	.144285	.143318	.142476
2.5	.159993	.158274	.156780	.155479
2.8	.175323	.172645	.170318	.168291
3.1	.188781	.184887	.181503	.178554
3.5	.205044	.199142	.194010	.189540
4.0	.224978	.215996	.208184	.201377
4.5	.246773	.234151	.223170	.213598
5.0	.271957	.255201	.240618	.227902
5.6	.307705	.285402	.265980	.249039
6.3	.357597	.328077	.302352	.279902
7.0	.416324	.378829	.346131	.317578
8.0	.515008	.464868	.421087	.382822
9.0	.630224	.566018	.509881	.460764
10.0	.761106	.681476	.611743	.550658
12.5	1.152443	1.028690	.919835	.824146
16.0	1.841354	1.644793	1.470064	1.315529
20.0	2.811081	2.518005	2.255192	2.020691

PRESSURE 151.50 DEPTH EQUIVALENT 5000.

	TEMPERATURE			
FREQ	65	70	75	80
2.0	.126825	.126438	.126099	.125801
2.2	.141741	.141097	.140533	.140037
2.5	.154343	.153349	.152477	.151710
2.8	.166520	.164972	.163613	.162418
3.1	.175979	.173726	.171749	.170012
3.5	.185635	.182218	.179219	.176584
4.0	.195430	.190225	.185657	.181642
4.5	.205234	.197912	.191486	.185837
5.0	.216789	.207059	.198513	.191008
5.6	.234229	.221258	.209870	.199856
6.3	.260267	.243065	.227960	.214674
7.0	.292595	.270699	.251467	.234547
8.0	.349517	.319935	.294116	.271395
9.0	.417719	.379950	.346744	.317509
10.0	.497078	.450030	.408644	.372190
12.5	.739084	.665927	.600673	.543121
16.0	1.178955	1.058329	.951736	.857508
20.0	1.812025	1.626740	1.462313	1.316484

	TEMPERATURE			
FREQ	85	90	95	100
2.0	.125538	.125306	.125101	.124919
2.2	.139600	.139214	.138873	.138570
2.5	.151035	.150439	.149911	.149444
2.8	.161366	.160437	.159615	.158886
3.1	.168431	.167129	.165933	.164873
3.5	.174261	.172211	.170397	.168788
4.0	.178103	.174978	.172215	.169763
4.5	.180356	.176461	.172572	.169123
5.0	.184389	.178544	.173373	.168786
5.6	.191026	.183233	.176335	.170217
6.3	.202960	.192614	.183460	.175339
7.0	.219628	.206449	.194785	.184439
8.0	.251352	.233645	.217972	.204066
9.0	.291714	.268918	.248737	.230829
10.0	.340015	.311574	.286388	.264036
12.5	.492274	.447289	.407431	.372036
16.0	.774102	.700209	.634660	.576399
20.0	1.187065	1.072170	.970081	.879223

PRESSURE 303.03 DEPTH EQUIVALENT 10000.

	TEMPERATURE			
FREQ	25	30	35	40
2.0	.131864	.130791	.129869	.129073
2.2	.150116	.148335	.146801	.145479
2.5	.167279	.164527	.162159	.160117
2.8	.186662	.182379	.178694	.175514
3.1	.205253	.199033	.193678	.189057
3.5	.229975	.220564	.212457	.205457
4.0	.262844	.248557	.236239	.225595
4.5	.299362	.279845	.262564	.247622
5.0	.342254	.315762	.292871	.273058
5.6	.400957	.365842	.335454	.309123
6.3	.480475	.434255	.394175	.359392
7.0	.571617	.513272	.462564	.418487
8.0	.721013	.643760	.576379	.517649
9.0	.891620	.793799	.708135	.633240
10.0	1.062022	.962204	.856808	.764341
12.5	1.636366	1.456873	1.296886	1.155117
16.0	2.572464	2.304394	2.059910	1.839449
20.0	3.816982	3.452965	3.110023	2.793003

	TEMPERATURE			
FREQ	45	50	55	60
2.0	.128386	.127790	.127273	.126822
2.2	.144336	.143345	.142485	.141735
2.5	.158352	.156822	.155492	.154334
2.8	.172765	.170382	.168310	.166506
3.1	.185060	.181595	.178582	.175958
3.5	.199400	.194148	.189581	.185602
4.0	.216381	.208388	.201435	.195376
4.5	.234680	.223447	.213674	.205155
5.0	.255386	.240974	.227995	.216678
5.6	.286281	.266432	.249146	.234069
6.3	.329185	.302912	.280016	.260036
7.0	.380157	.346786	.317685	.292274
8.0	.466471	.421847	.382882	.348826
9.0	.567823	.510681	.460718	.417004
10.0	.653366	.612495	.550433	.496068
12.5	1.030022	.919883	.823000	.737838
16.0	1.642279	1.466894	1.311386	1.173849
20.0	2.504040	2.243202	2.009296	1.800591

PRESSURE 303.03 DEPTH EQUIVALENT 10000.

FREQ	TEMPERATURE 65	70	75	80
2.0	.126428	.126084	.125782	.125517
2.2	.141081	.140508	.140006	.139564
2.5	.153323	.152438	.151662	.150980
2.8	.164931	.163552	.162343	.161280
3.1	.173666	.171661	.169902	.168355
3.5	.182127	.179085	.176417	.174071
4.0	.190084	.185451	.181386	.177812
4.5	.197711	.191195	.185476	.180448
5.0	.206787	.198127	.190526	.183842
5.6	.220836	.209343	.199208	.190296
6.3	.242561	.227251	.213807	.201983
7.0	.270036	.250551	.233434	.218376
8.0	.319006	.292857	.269878	.249656
9.0	.378594	.345079	.315526	.289507
10.0	.448382	.406509	.369675	.337231
12.5	.662932	.597022	.538946	.487727
16.0	1.052296	.944943	.850074	.766211
20.0	1.614378	1.449974	1.303633	1.173847

FREQ	TEMPERATURE 85	90	95	100
2.0	.125283	.125077	.124894	.124732
2.2	.139175	.138832	.138528	.138259
2.5	.150379	.149848	.149379	.148963
2.8	.160343	.159516	.158785	.158136
3.1	.166992	.165790	.164726	.163782
3.5	.172004	.170179	.168564	.167133
4.0	.174562	.171882	.169422	.167240
4.5	.176016	.172103	.168642	.165572
5.0	.177951	.172749	.168146	.164064
5.6	.182439	.175501	.169362	.163917
6.3	.191557	.182350	.174202	.166975
7.0	.205097	.193368	.182988	.173779
8.0	.231816	.216059	.202110	.189734
9.0	.266550	.246262	.228300	.212362
10.0	.308595	.283282	.260867	.240974
12.5	.442472	.402436	.366961	.335459
16.0	.691979	.626214	.567875	.516024
20.0	1.058662	.956408	.865547	.784683

PRESSURE 454.50 DEPTH EQUIVALENT 15000.

FREQ	TEMPERATURE 25	30	35	40
2.0	.130796	.129855	.129047	.128350
2.2	.148342	.146779	.145435	.144276
2.5	.164535	.162125	.160048	.158258
2.8	.182386	.178634	.175405	.172618
3.1	.199039	.193587	.188894	.184843
3.5	.220556	.212308	.205203	.199067
4.0	.248511	.235989	.225193	.215864
4.5	.279722	.262176	.247032	.233936
5.0	.315519	.292300	.272237	.254872
5.6	.365374	.334598	.307964	.284886
6.3	.433383	.392872	.357744	.327259
7.0	.511811	.460675	.416231	.377599
8.0	.641048	.573339	.514284	.462810
9.0	.789242	.703506	.628426	.562782
10.0	.955062	.850047	.757670	.676629
12.5	1.439087	1.281767	1.141544	1.017290
16.0	2.258045	2.023094	1.808821	1.615595
20.0	3.347855	3.028809	2.728237	2.450382

FREQ	TEMPERATURE 45	50	55	60
2.0	.127747	.127225	.126771	.126377
2.2	.143274	.142406	.141651	.140994
2.5	.156711	.155370	.154204	.153189
2.8	.170208	.168119	.166304	.164722
3.1	.181340	.178303	.175663	.173363
3.5	.193759	.189155	.185153	.181665
4.0	.207786	.200782	.194689	.189378
4.5	.222593	.212748	.204181	.196715
5.0	.239822	.226752	.215376	.205457
5.6	.264860	.247469	.232319	.219105
6.3	.300784	.277757	.257690	.240178
7.0	.344005	.314757	.289251	.266979
8.0	.417954	.378843	.344692	.314844
9.0	.505443	.455366	.411575	.373262
10.0	.605658	.543543	.489149	.441500
12.5	.907651	.811118	.726205	.651564
16.0	1.442783	1.289066	1.152771	1.032225
20.0	2.197117	1.968508	1.763500	1.580578

PRESSURE 454.50 DEPTH EQUIVALENT 15000.

FREQ	TEMPERATURE 65	70	75	80
2.0	.126032	.125730	.125465	.125233
2.2	.140421	.139919	.139479	.139092
2.5	.152303	.151528	.150847	.150250
2.8	.163342	.162133	.161073	.160142
3.1	.171355	.169597	.168055	.166699
3.5	.178619	.175954	.173615	.171559
4.0	.184740	.180679	.177116	.173984
4.5	.190191	.184479	.179467	.175060
5.0	.196789	.189198	.182536	.176678
5.6	.207552	.197434	.188551	.180740
6.3	.224362	.211443	.199661	.189297
7.0	.247490	.230411	.215409	.202211
8.0	.288708	.265790	.245650	.227926
9.0	.339685	.310224	.284321	.261517
10.0	.399704	.363005	.330721	.302286
12.5	.585913	.528146	.477245	.432353
16.0	.925693	.831601	.748451	.674950
20.0	1.417810	1.273279	1.145020	1.031265

FREQ	TEMPERATURE 85	90	95	100
2.0	.125028	.124847	.124687	.124545
2.2	.138751	.138450	.138184	.137948
2.5	.149723	.149258	.148846	.148482
2.8	.159321	.158596	.157955	.157387
3.1	.165505	.164451	.163518	.162691
3.5	.169747	.168148	.166733	.165478
4.0	.171223	.168787	.166631	.164718
4.5	.171176	.167747	.164713	.162022
5.0	.171515	.166955	.162922	.159344
5.6	.173854	.167773	.162392	.157620
6.3	.180160	.172090	.164949	.158614
7.0	.190573	.180293	.171195	.163124
8.0	.212292	.198480	.186254	.175407
9.0	.241395	.223614	.207872	.193902
10.0	.277188	.255002	.235357	.217921
12.5	.392689	.357599	.326507	.298898
16.0	.609389	.552249	.501118	.455673
20.0	.930314	.840691	.761056	.690183